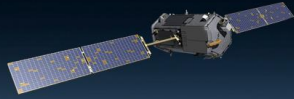


Measuring Atmospheric CO₂ with the NASA Orbiting Carbon Observatory-2 (OCO-2)

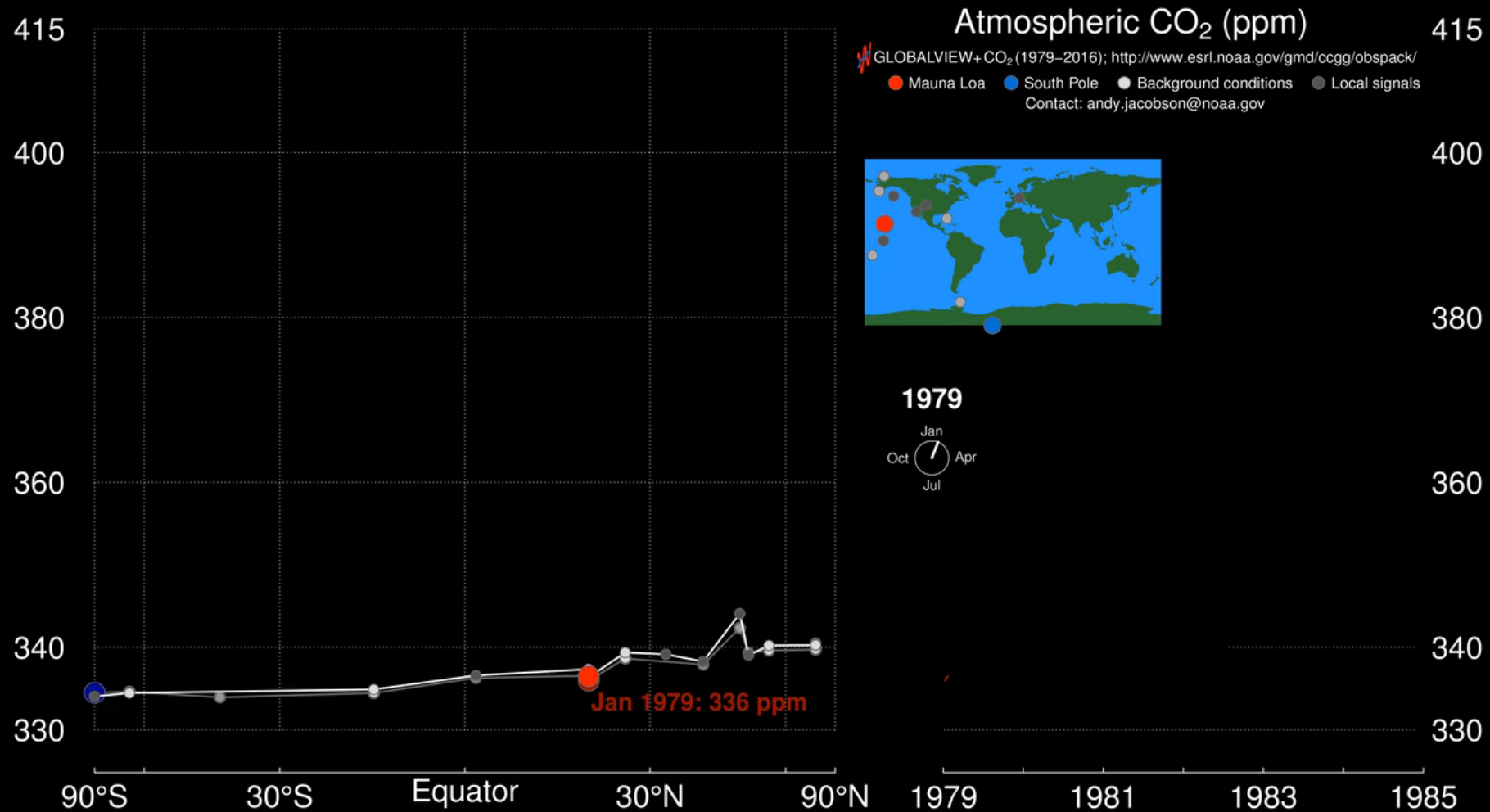


Los Angeles Basin

David Crisp, for the OCO-2 Science Team
Jet Propulsion Laboratory, California
Institute of Technology

7 February 2017

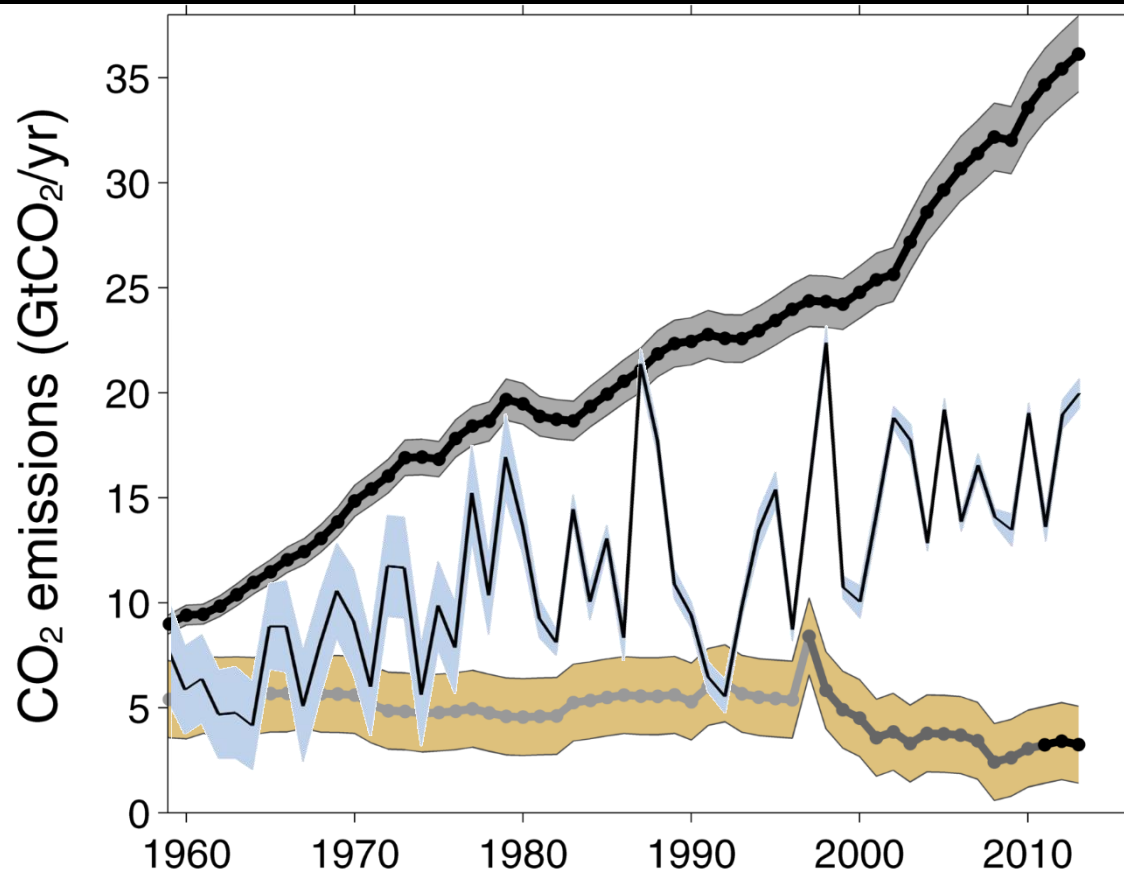
Copyright 2017 California Institute of Technology.
Government sponsorship acknowledged.



Andy Jacobson, NOAA ESRL GMD



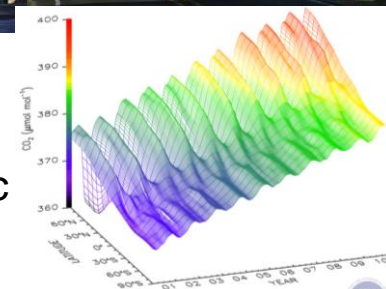
What Processes Control CO₂?



Fossil fuels
and cement



Atmospheric
growth rate



Land-use
change

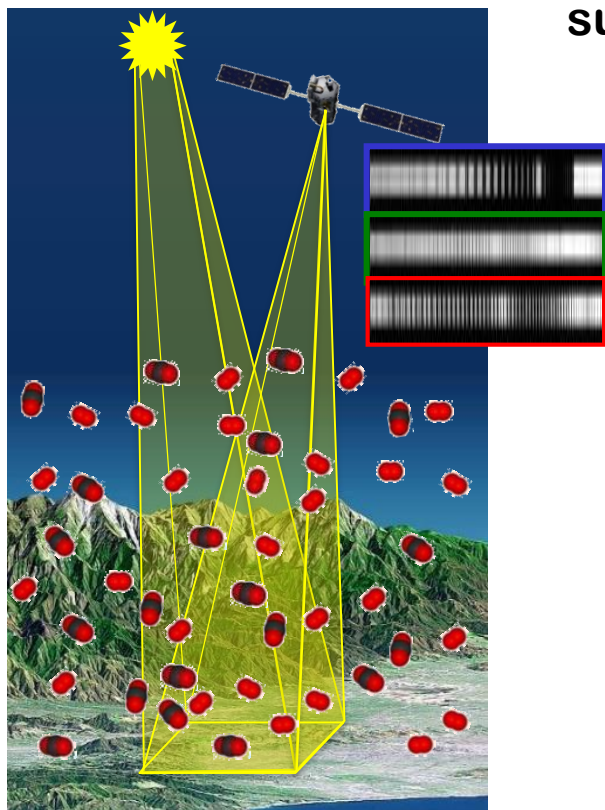




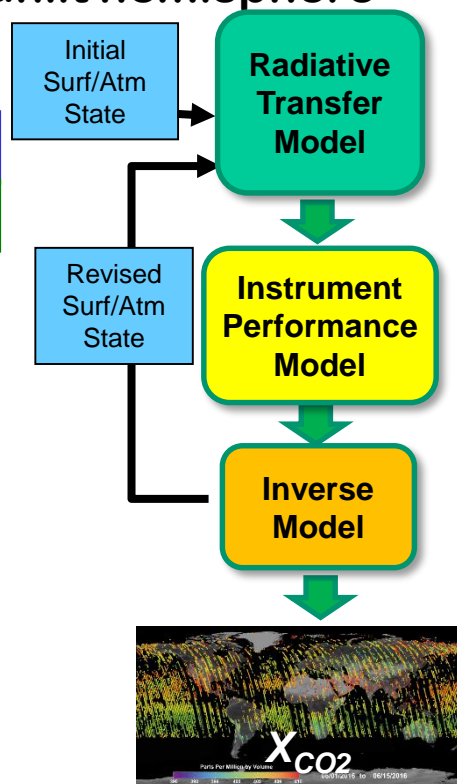


Measuring CO₂ from Space

- Record spectra of CO₂ and O₂ absorption in reflected sunlight



Retrieve variations in the **column averaged CO₂ dry air mole fraction, X_{CO_2}** over the sunlit hemisphere

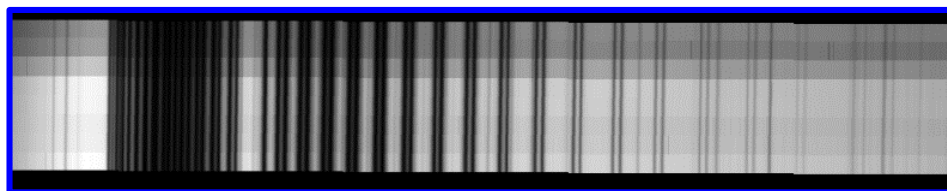
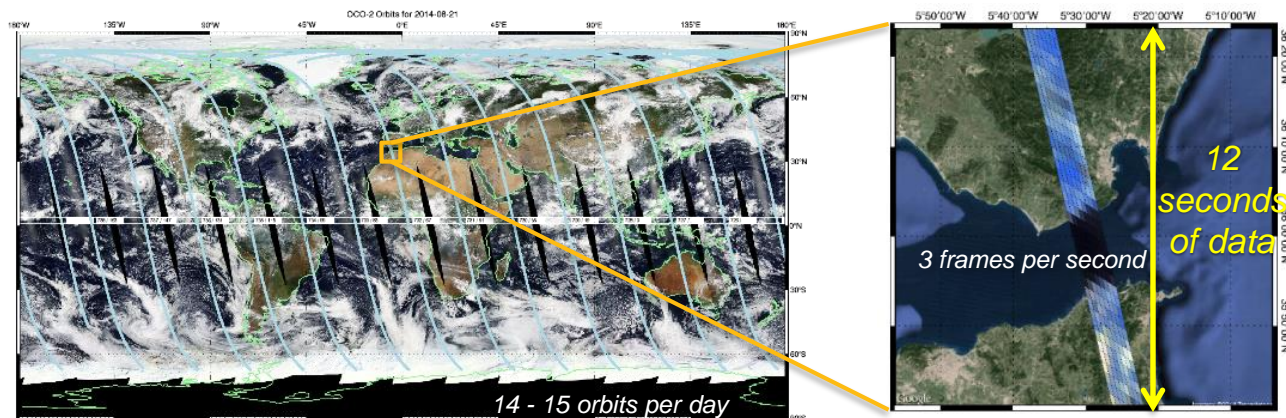


Validate measurements to ensure X_{CO_2} accuracy of 1 ppm (0.25%)





OCO-2 Sampling Approach



O₂ A-Band

CO₂ 1.61 μm Band

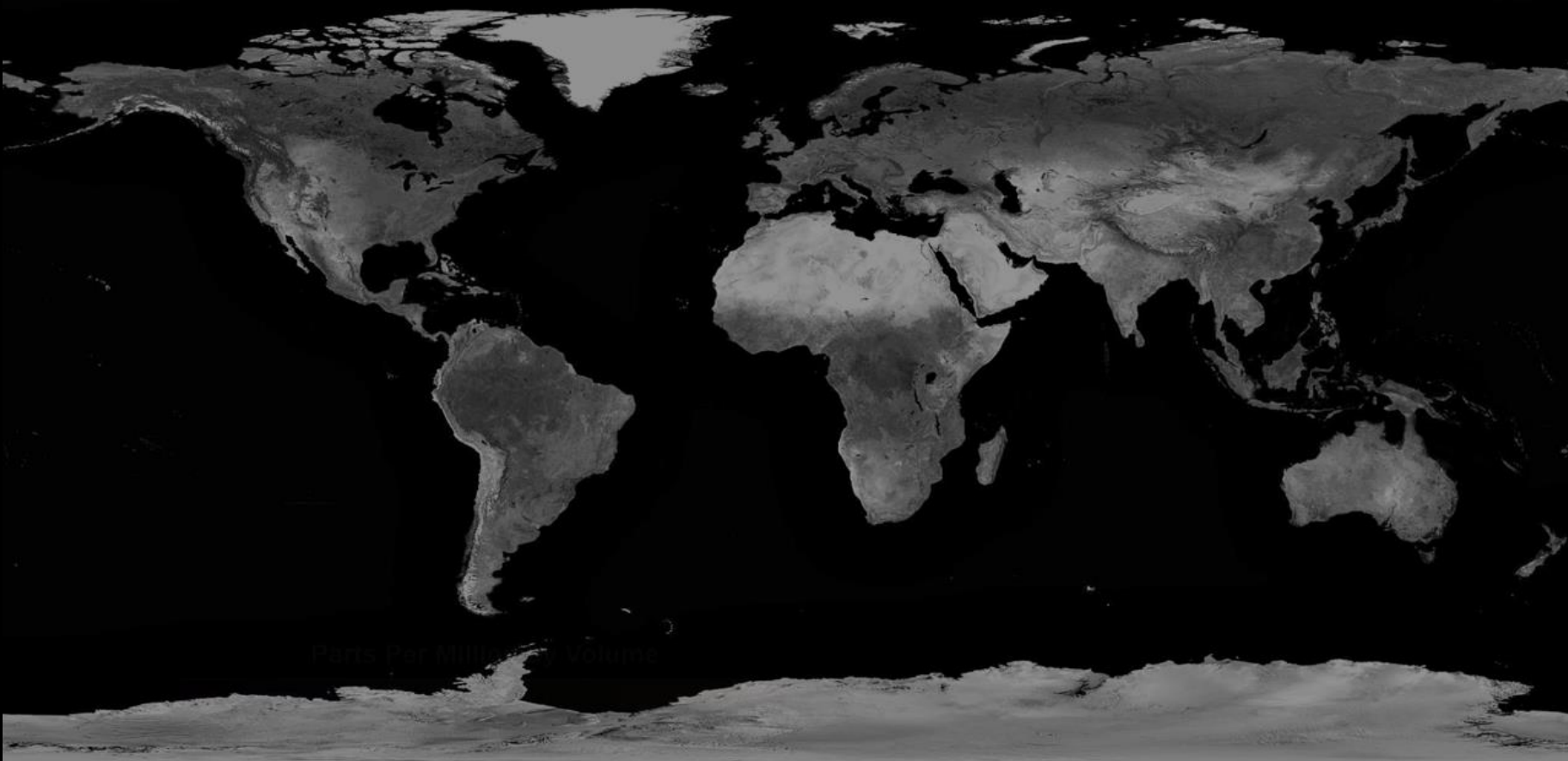
CO₂ 2.06 μm Band

The OCO-2 instrument collects 24 soundings each second as it flies over the sunlit hemisphere of the Earth, yielding almost 1 million soundings each day

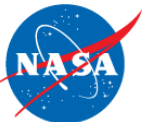


A Quick Look at the OCO-2 Prime Mission

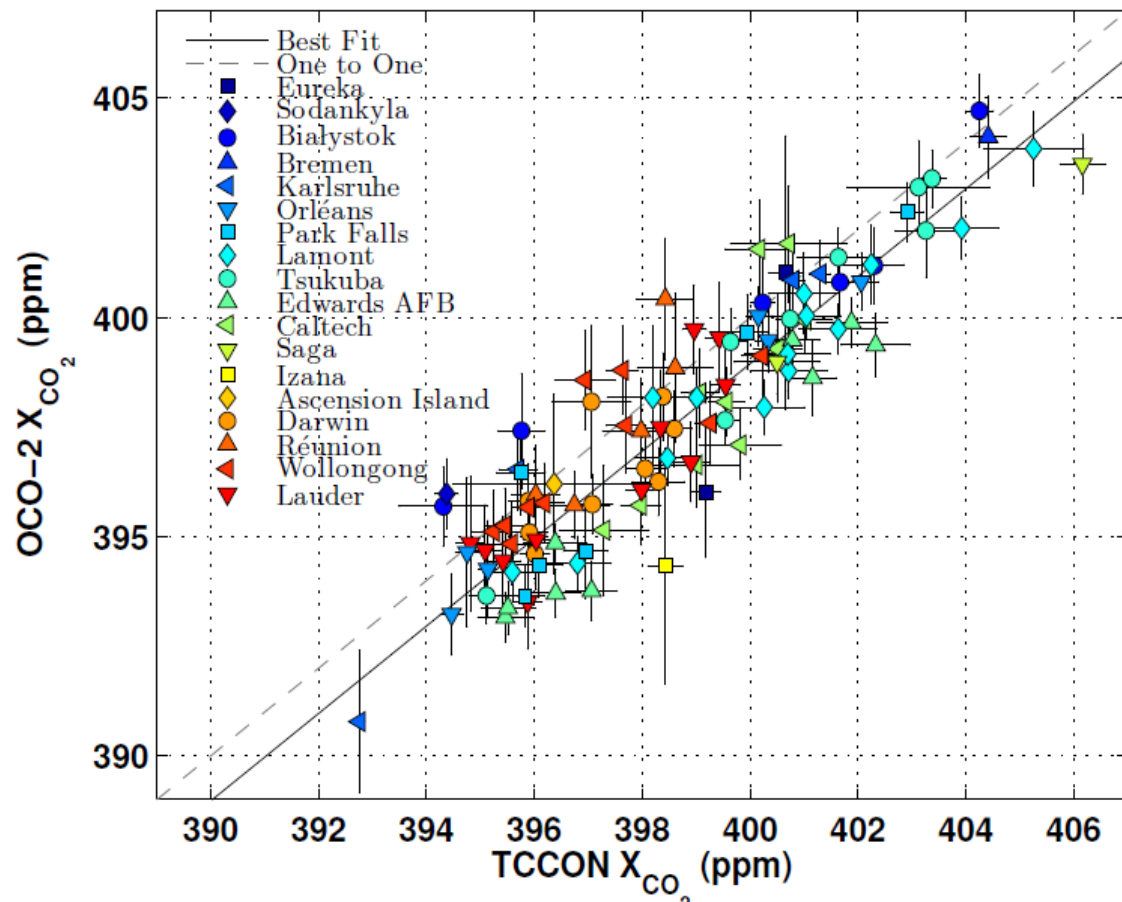
Orbiting Carbon Observatory - 2
Atmospheric Carbon Dioxide Concentration (09/06/14 - 08/10/2016)



Parts Per Million by Volume



Comparison of TCCON and OCO-2 X_{CO_2}



Comparisons with the Total Carbon Column Observing Network (TCCON) stations are being used to identify and correct biases in target observations.

After applying a bias correction

- Global bias is reduced to < 1 ppm
- Station-to-station biases reduced to ~ 1.5 ppm

Wunch et al. (2016)



UNIVERSITY OF
WOLLONGONG



National
Institute for
Environmental
Studies, Japan

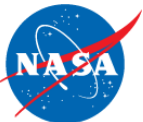


NIWA
Taihoro Nukurangi

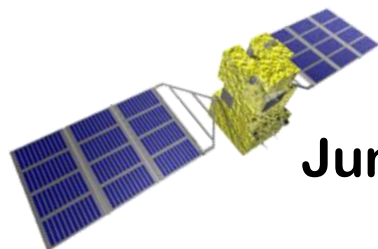


Universität
Bremen

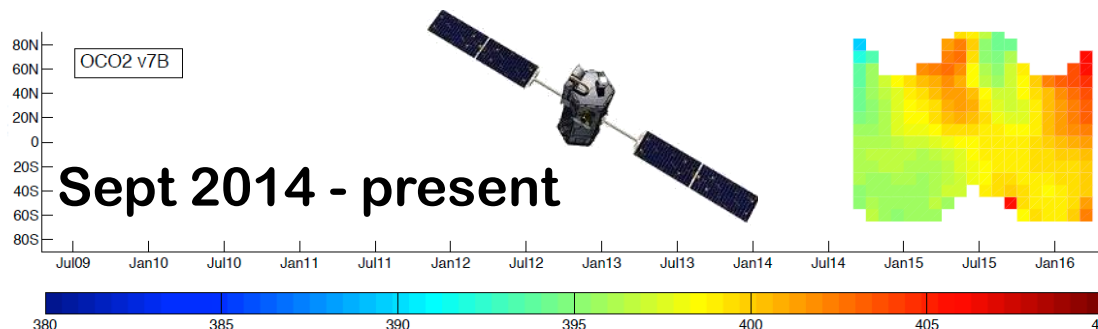
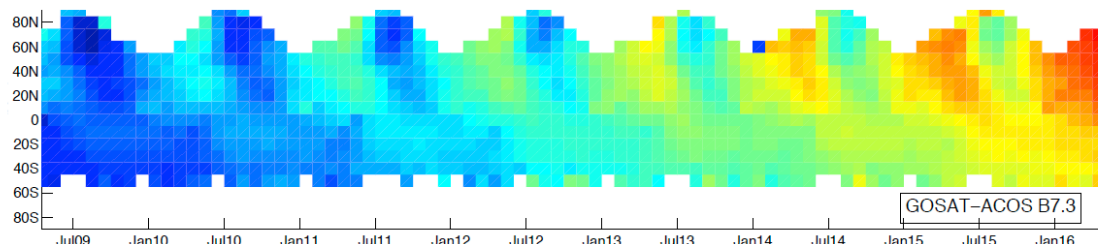




ACOS/GOSAT B7.3, and OCO-2 v7 XCO₂

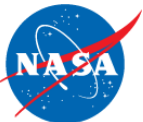


June 2009 - present

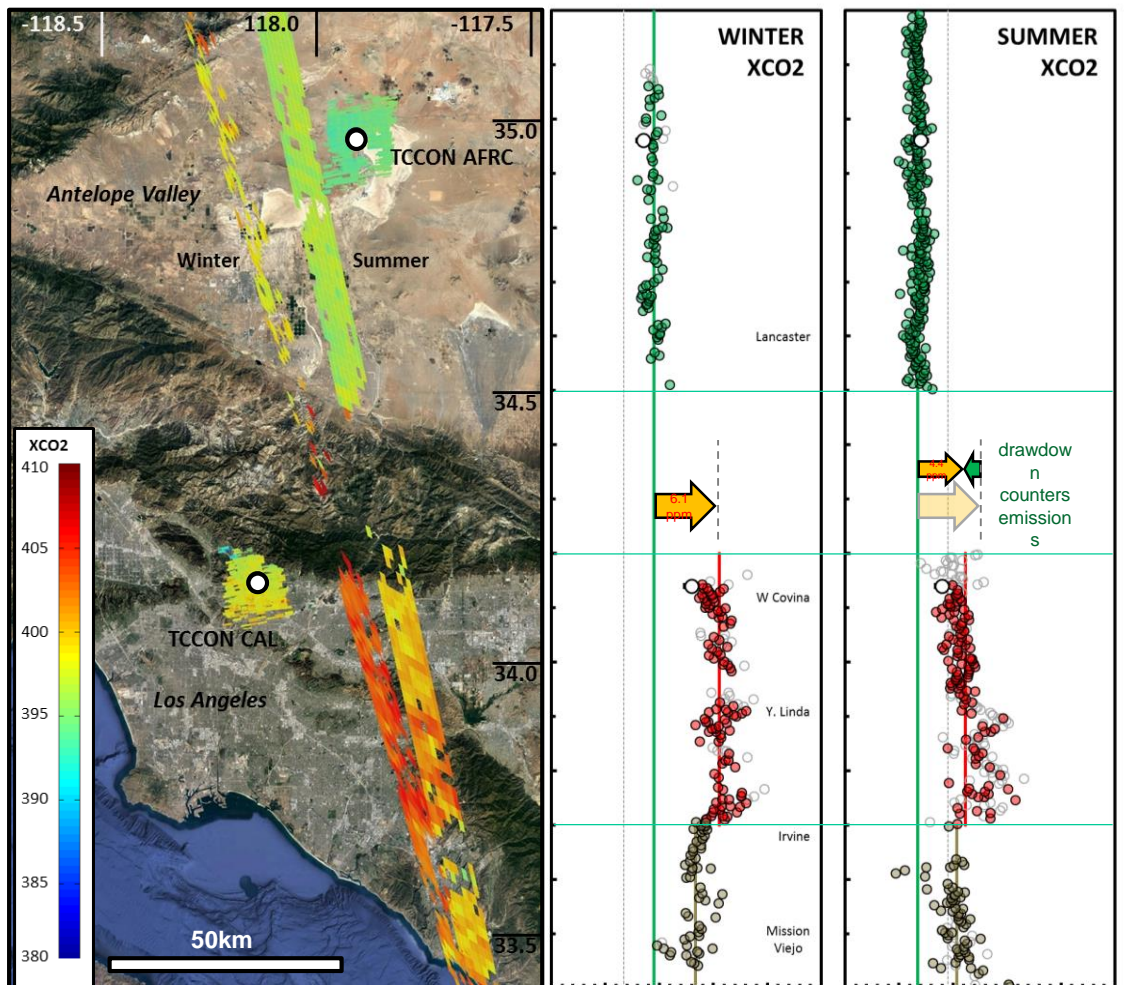


TCCON and other standards have been used to cross validate OCO-2 and GOSAT X_{CO₂} to extend the climate data record

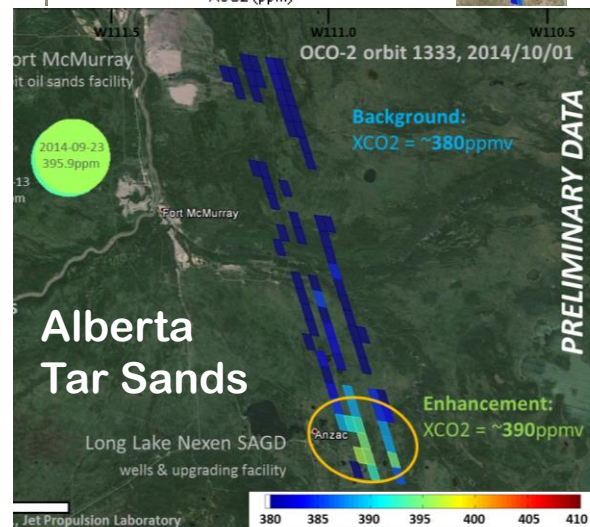
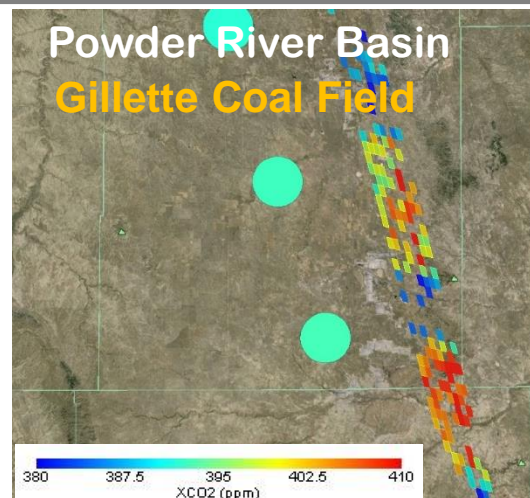
- The magnitude of differences between GOSAT-ACOS B7.3 and OCO2 v7r are within ± 1 ppm for overlap regions



Localized Sources



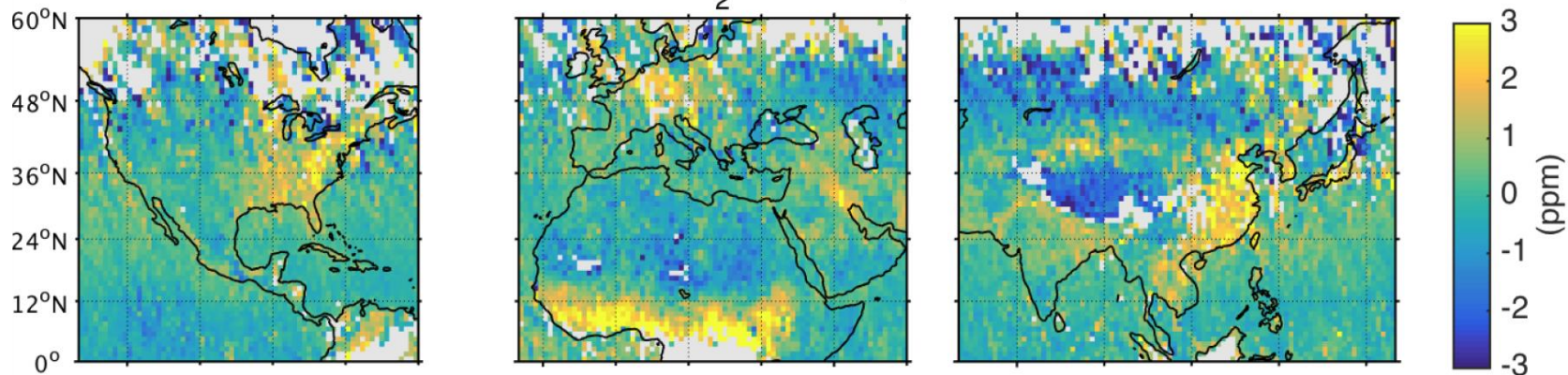
Los Angeles Basin



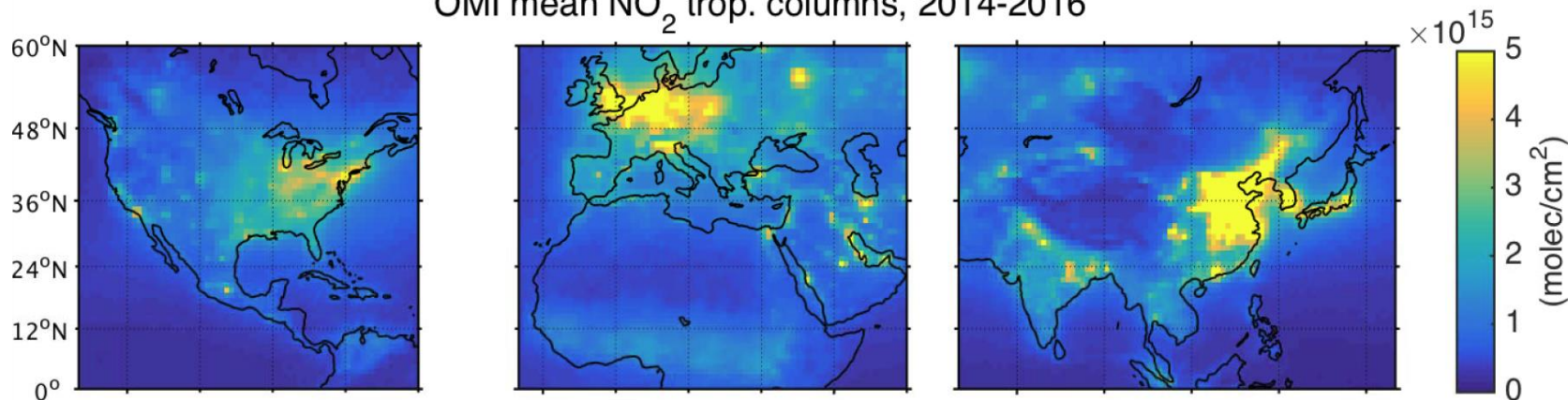
Florian Schwandner et al.(Submitted)

Anthropogenic Emissions

OCO-2 mean XCO_2 anomalies, 2014-2016



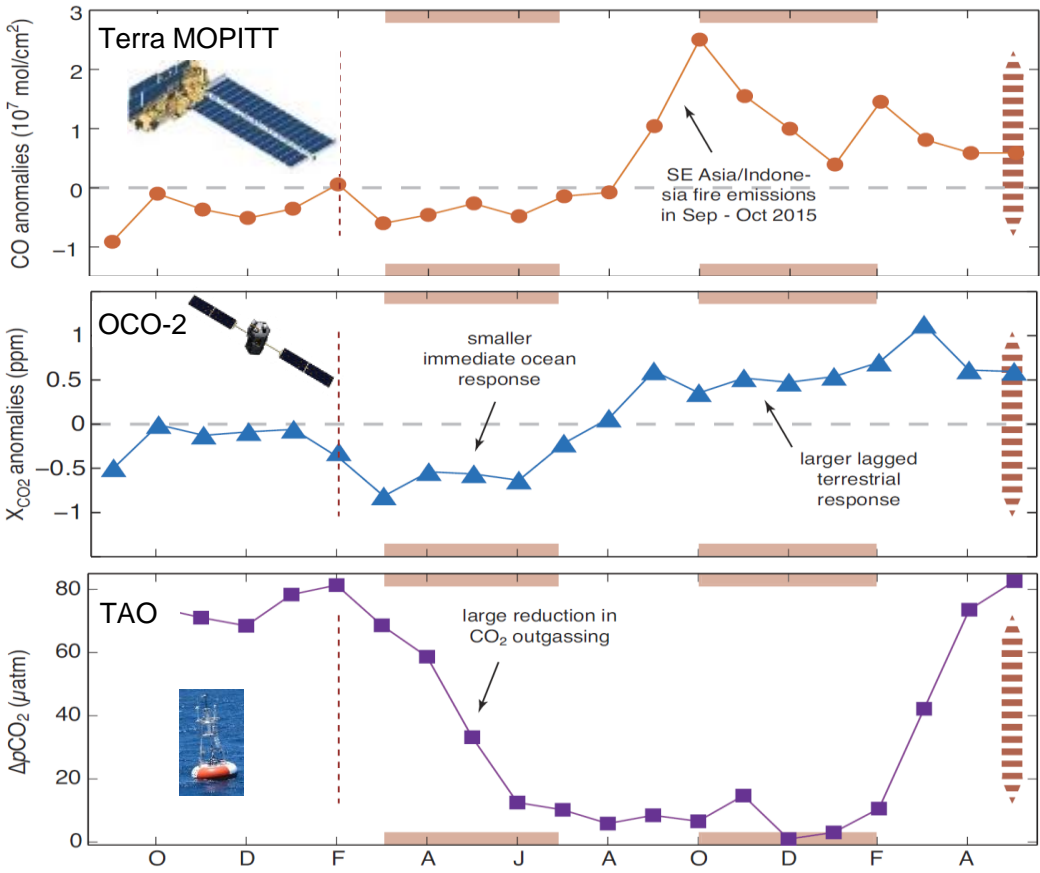
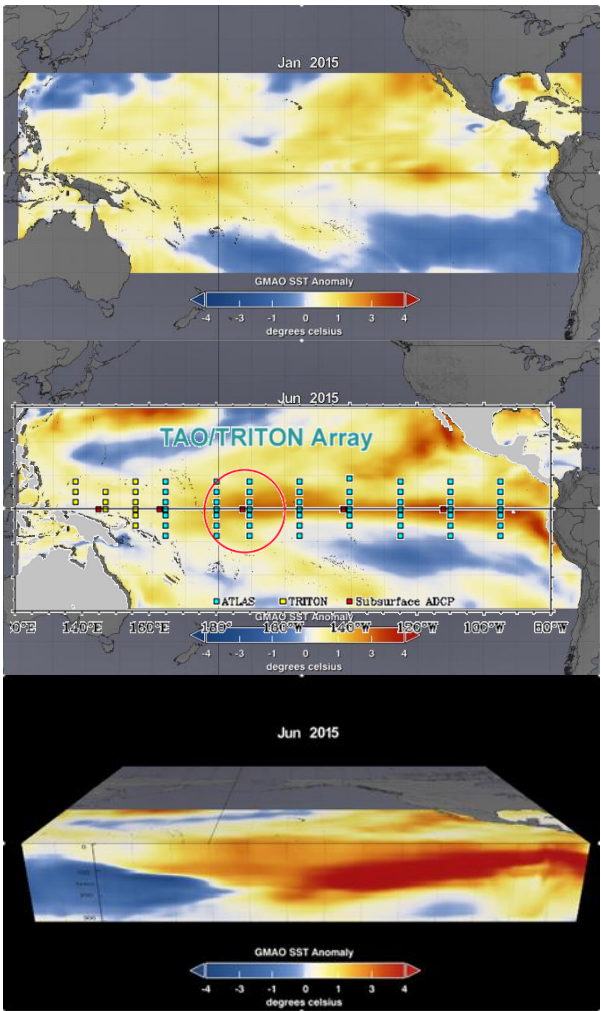
OMI mean NO_2 trop. columns, 2014-2016



Janne Hakkarainen et al. GRL (2016)



2015-2016 El Niño: Ocean Response

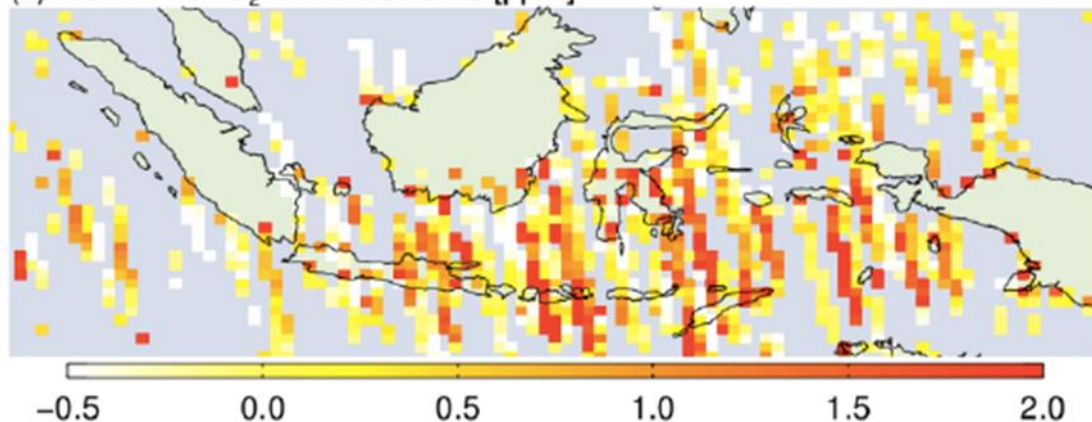


Abhishek Chatterjee et al. (submitted)



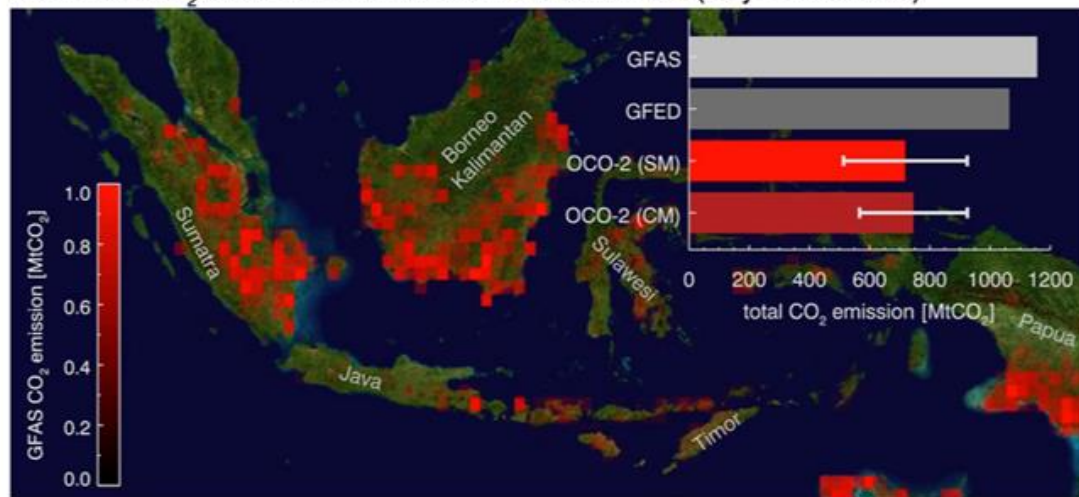
2015-2016 El Niño: Fires

(c) OCO-2 XCO₂ enhancements [ppm]



X_{CO2} enhancements over Indonesia observed by OCO-2 between July and November 2015.

Estimated CO₂ emission for the 2015 Indonesian fires (July - November)

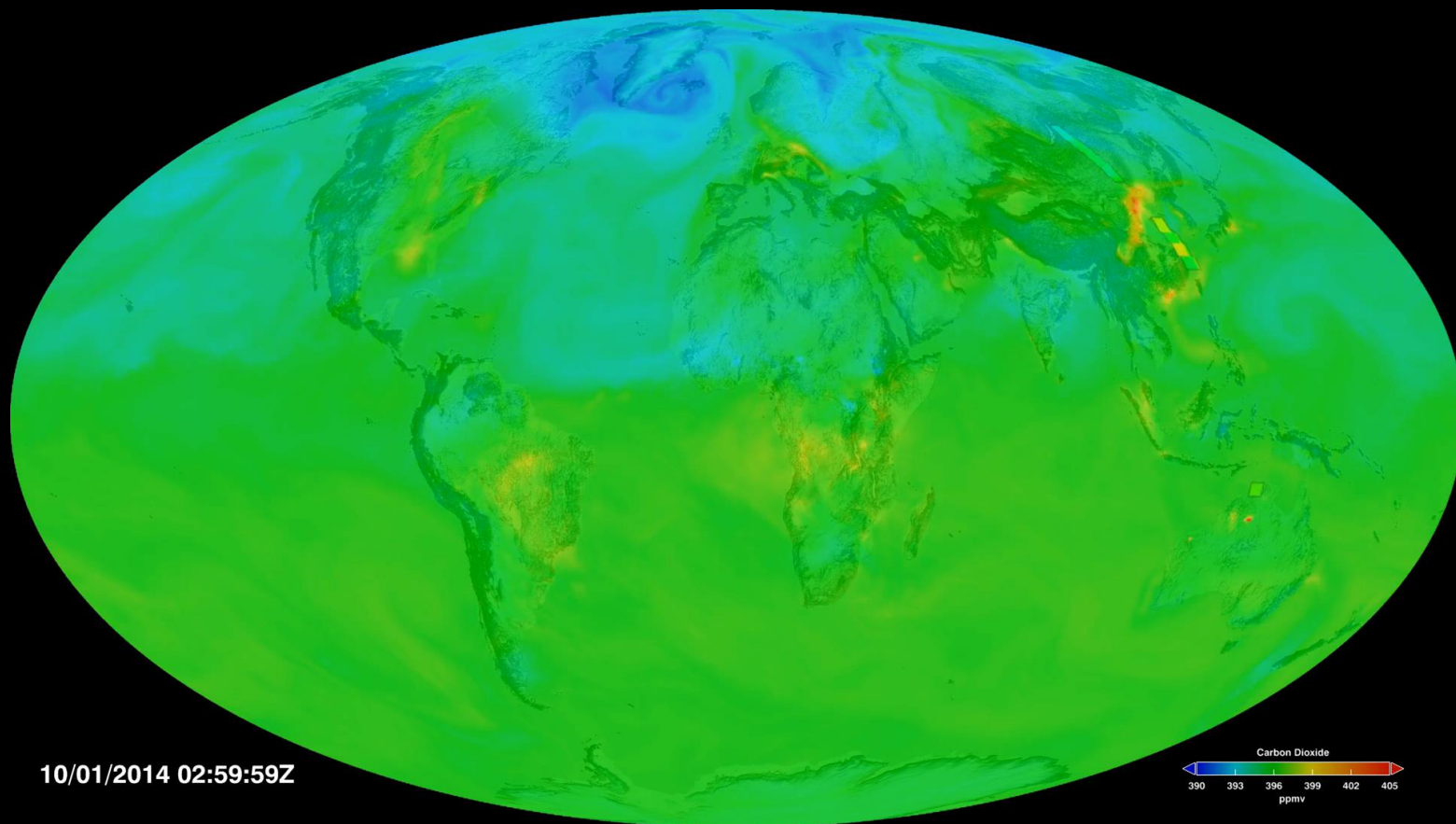


Fire emissions estimates from the GFAS and GFED inventories to emission estimates obtained from OCO-2 data, using two analysis approaches. The OCO-2 estimates are less than 70% as large as those in the inventories.

Jenns Heymann et al. (GRL, Accepted 2017)



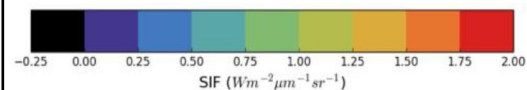
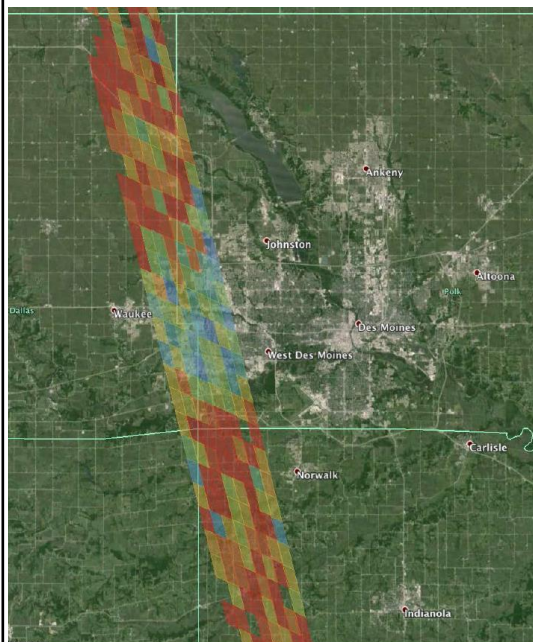
Assimilation of OCO-2 X_{CO_2}



Brad Weir et al. GSFC GMAO

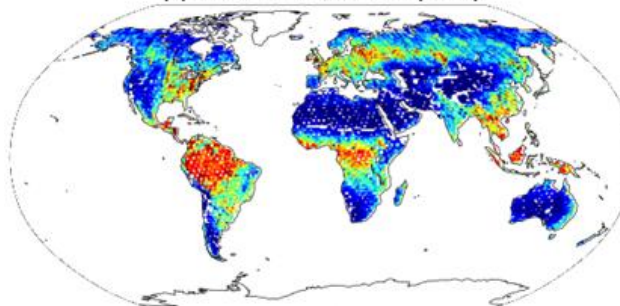


Solar Induced Chlorophyll Fluorescence (SIF)

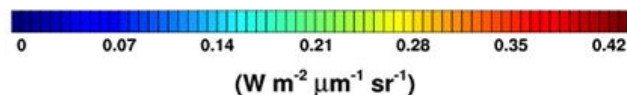
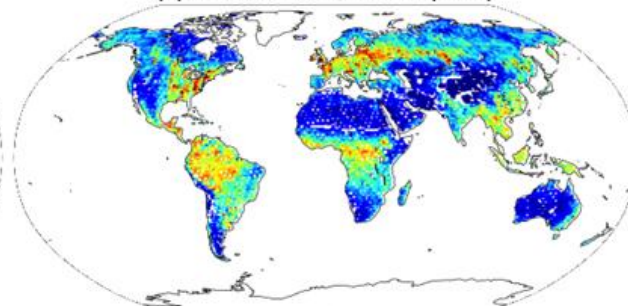


**OCO-2 SIF over
Des Moines, Idaho**

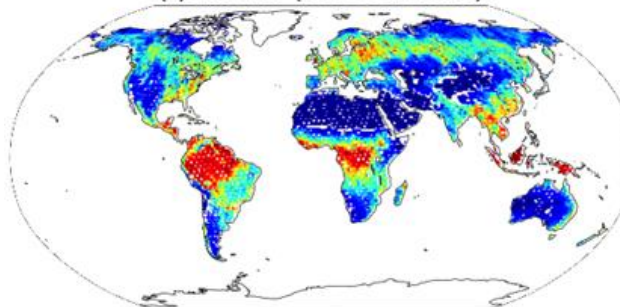
(a) OCO-2 SIF @757nm (2015)



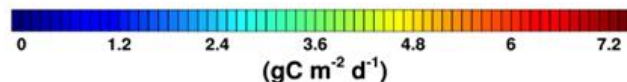
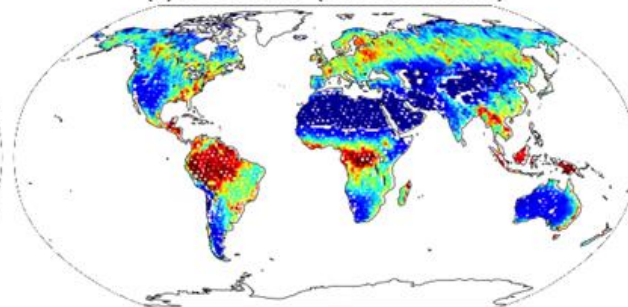
(b) GOME-2 SIF @740nm (2015)



(c) MPI GPP (2009-2012 mean)



(d) MODIS GPP (2009-2012 mean)

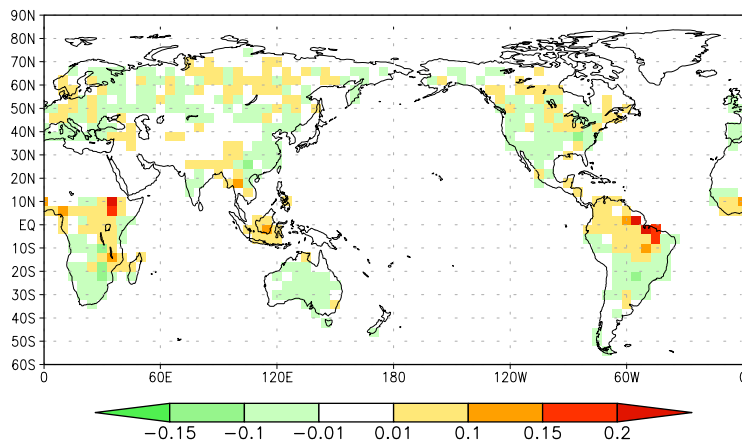


Ying Sun et al. (submitted 2017)

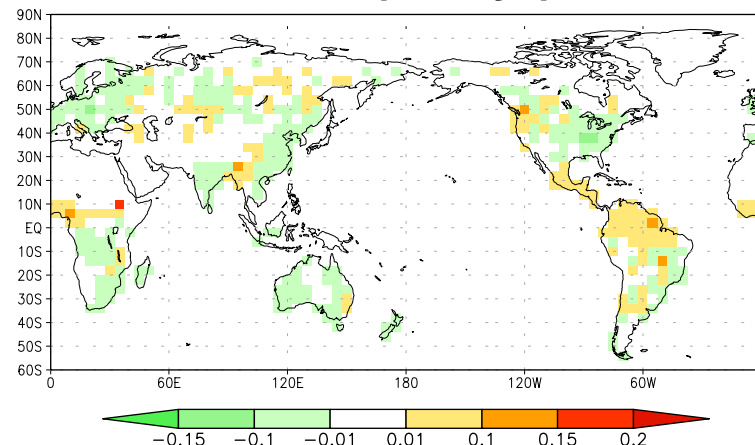


2015 El Niño and 2011 La Niña annual biosphere fluxes and their differences

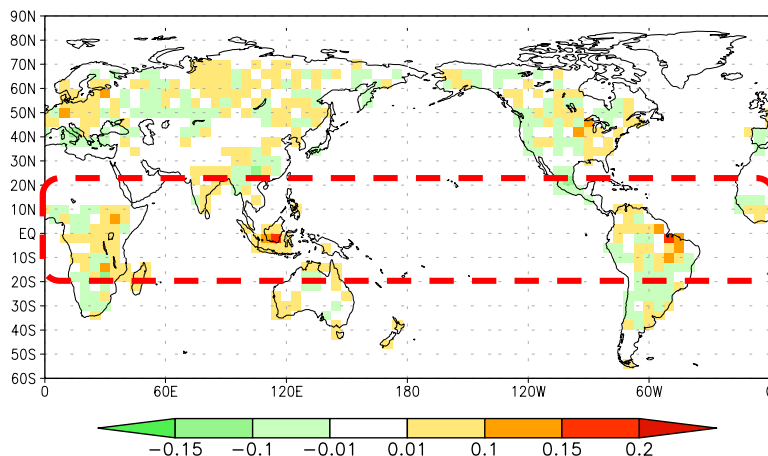
2015 (GtC/yr)



2011 (GtC/yr)



2015- 2011 (GtC/yr)



Red: release CO₂ into atmosphere

Green: absorb CO₂ from atmosphere

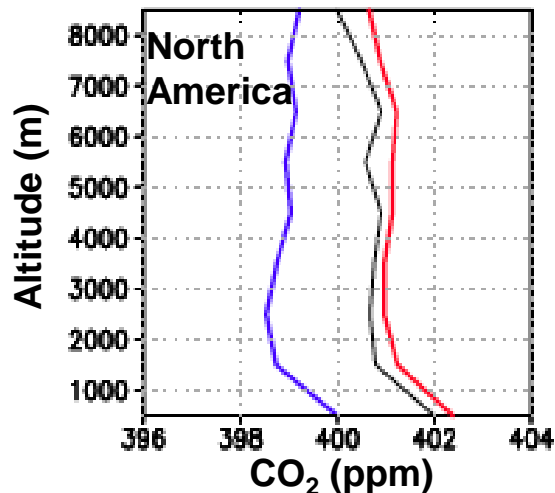
- The most significant impact of 2015 El Niño on biosphere carbon fluxes is the increase of CO₂ release from the tropics

Junjie Liu et al. (Submitted 2017)

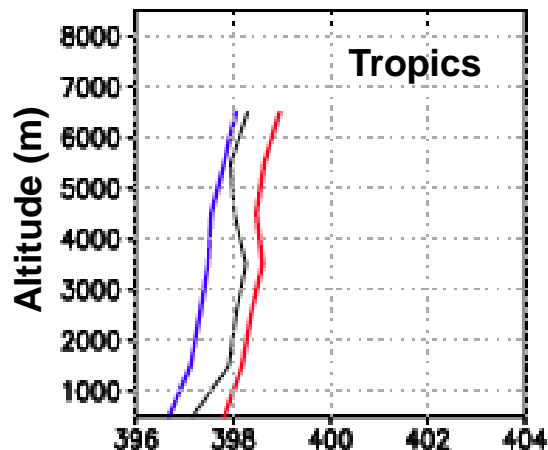


Validating Regional Flux Changes

Aircraft vs OCO-2

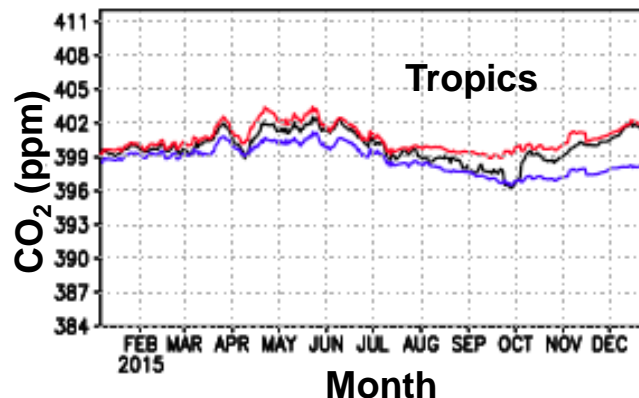
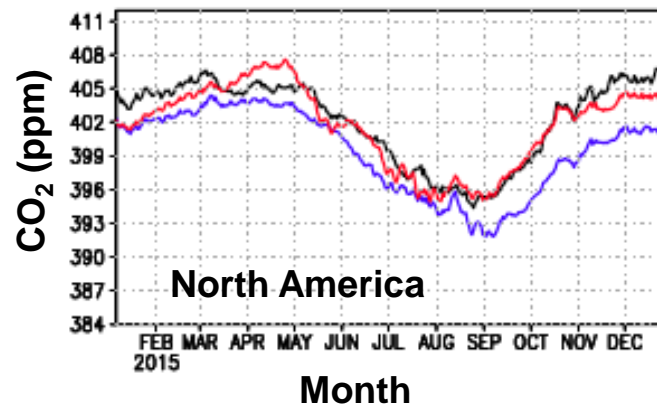


Junjie Liu et al. compare modeled profiles derived in their studies to aircraft and modeled in situ surface values to flask in situ measurements



- Blue: model prior
- Red: model posterior
- Black: in situ observation

Surface Flask vs OCO-2





2015-2016 El Niño: 3 Continents, 3 Stories

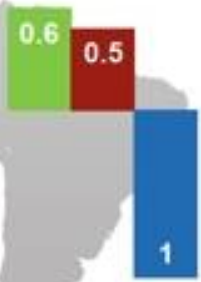
Reduced GPP

Increased Respiration

Fire

- NBE (2015-2011), GtC/yr
- T (2015-2011), K
- Precip (2015-2011), mm/day

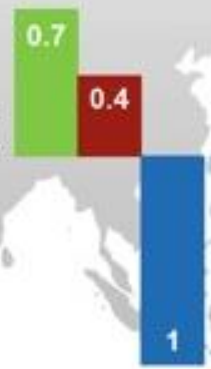
AMAZON



AFRICA



SOUTH EAST ASIA



AUSTRALIA





Evolving Carbon Measurement Capabilities

PAST



Two New CO₂ missions selected :

- NASA Earth Ventures GeoCarb
- CNES confirms MicroCarb

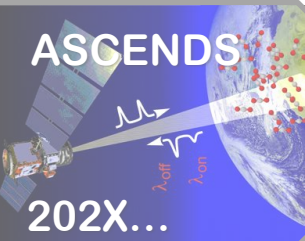
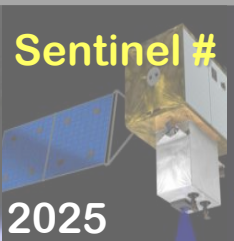
PRESENT



NEAR FUTURE



LATER





Summary

- **OCO-2 was successfully launched on 2 July 2014, and started its first extended mission on October 16, 2016**
 - **Now returning about 100,000 full-column measurements of X_{CO_2} each day over the sunlit hemisphere**
 - **These products are being validated against TCCON and other standards to assess their accuracy**
- **Over 27 months of data have been delivered to the Goddard Earth Sciences Data and Information Services Center (GES-DISC) for distribution to the science community**

<http://disc.sci.gsfc.nasa.gov/OCO-2>
- **These products are now being used by the carbon cycle science community to identify and quantify the CO_2 sources and sinks on regional scales over the globe**

Thank You for Your Attention

Questions?